REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1 to 11 in the underlying PCT Application No. PCT/DE03/02507, and adds new claims 12 to 22. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and § 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE03/02507 includes an International Search Report, dated December 2, 2003, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is asserted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

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IMAGING SENSOR

~~Background of the Invention~~ FIELD OF THE INVENTION

The present invention ~~proceeds from an imaging sensor of the species defined in the independent claim.~~ relates to an imaging sensor.

BACKGROUND INFORMATION

~~WO 01/60662 A1 has already disclosed an~~ Imaging sensors may be applicable to safety-relevant applications such as vehicle occupant protection systems. An imaging sensor that is disposed in a vehicle is discussed in published international patent document WO 01/60662. It is used therein for seat occupancy detection. A conventional imaging sensor requires additional sensors for monitoring the imaging sensor's operational capabilities.

~~Advantages of the Invention~~ SUMMARY

~~The imaging sensor according to~~ In an example embodiment of the present invention ~~having the features of the independent claim has, in contrast, the advantage that the imaging sensor monitors its functionality~~, an imaging sensor may monitor its operability on the basis of its image signal. A safety requirement for an image recognition system of this kind ~~is thereby met. The imaging sensor can be used~~ may be thereby met. Thus, an additional sensor suite for monitoring operability may be no longer necessary, or the demands on additional monitoring apparatuses may be reduced. The imaging sensor may be used, e.g., for occupant detection, ~~for~~ determination of the occupant's posture, ~~or~~ for classification of the occupancy situation, ~~but also for~~ surroundings monitoring ~~and also, for example, for~~, and/or rollover detection.

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In an example embodiment, the imaging sensor may have ~~particular, an additional sensor suite for monitoring functionality is thus no longer necessary, or the demands on additional monitoring apparatuses can be reduced. Imaging sensors are applicable here, in particular, in safety-relevant applications such as occupant protection systems. It is specifically here that functionality of the imaging sensor is essential for functionality.~~

~~The features and refinements set forth in the dependent claims make possible advantageous improvements to the imaging sensor described in the independent claim.~~

~~It is particularly advantageous that the imaging sensor has~~ an evaluation unit that ~~derives~~ may derive from the image signal at least one value that the evaluation unit ~~compares~~ may compare with at least one limit value in order to monitor ~~functionality~~ operability. Empirical knowledge about measurement signal profiles ~~can~~ may then be incorporated. ~~It is possible in this context, in particular, to compare~~ In one example embodiment, the derived value may be compared with a limit value set that is stored in a memory associated with the imaging sensor. ~~A~~ In an example embodiment, a system state~~, in particular, can~~ may be determined by ~~the~~ a comparison with several limit values. ~~Advantageously, that~~ The system state ~~is~~ may be then transmitted via an interface to further systems. ~~That~~ The interface ~~can~~ may be embodied, e.g., as a two-wire interface, for example to a control unit, ~~but it can also be embodied~~ or as a bus interface. Optical, electrical, or radio bus configurations, for example, ~~can then~~ may be used therefor.

~~It is further advantageous that~~ In an example embodiment, the imaging sensor ~~generates~~ may generate the image signal on the

basis of at least one invariant pattern. That invariant image signal ~~is~~ may be then used for self-monitoring by being compared with an internal reference pattern. Naturally occurring invariant features of the surroundings; ~~or~~ invariant features automatically induced by a system, for example using an illumination module; or artificially induced invariant features of the surroundings, for example targets that are provided or generated by a test image ~~process, can~~ procedure, may be used for this purpose. In the test image ~~process~~ procedure, a simulated sensor signal ~~is~~ may be conveyed to the evaluation unit. The associated measurement signal ~~is~~ may be predefined. Discrepancies may then result in an error message.

~~It is further advantageous that~~ In an example embodiment, the imaging sensor ~~monitors its functionality~~ may monitor its operability on the basis of a profile of the image signal. This can be accomplished, for example, by way of a simple comparison of adjacent regions of the imaging sensor. A pattern comparison, i.e., a comparison with qualitative signal profiles, ~~is~~ may also be possible here. Trends or statistical parameters ~~can~~ may be analyzed, or correlation methods ~~can~~ may be applied to the image signal profile. Spectral methods such as analysis of the Fourier spectrum, the wavelet spectrum, or the contrast spectrum ~~can~~ may also~~, however,~~ be applied here.

~~It is additionally advantageous that~~ In an example embodiment, if the imaging sensor has at least two image-producing sensors, it ~~checks~~ may check its ~~functionality~~ operability by comparing the output signals of those two image-producing sensors. The redundancy of a network of high-resolution sensors, for example an array or also a stereocamera, ~~can~~ may thereby be utilized. Methods for analysis of the image signal profile ~~are then~~ may be applicable here as well. Utilization of a time-related redundancy ~~is~~ may also be possible here, by

way of a time-related analysis of the sensor signal or analysis of recorded dynamic processes.

The self-monitoring of the imaging sensor ~~can~~ may be performed in an initialization phase ~~or~~. It may also be performed continuously or intermittently during operation.

~~It is additionally advantageous that~~ In an example embodiment, the imaging sensor ~~is~~ may be connectable to a diagnostic unit that ~~activates~~ may activate the self-monitoring of the imaging sensor. ~~That~~ The diagnostic unit ~~can~~ may be disposed in the vehicle ~~or also~~ and/or outside the vehicle, in order then to perform the self-monitoring via a radio connection. ~~It is conceivable for an~~ An expanded test program may also ~~to~~ be performed in the event of an activation by the diagnostic unit, since it ~~is~~ may be possible, for example, to transfer pattern files or also to perform long-term tests. ~~It may furthermore be advantageous for~~ In an example embodiment, the imaging sensor ~~to~~ may be manually activatable for self-monitoring. The imaging sensor may then ~~has~~ have corresponding operating elements or interfaces ~~for that purpose,~~ which may initiate the self-monitoring by way of an actuation of a device.

~~The~~ In an example embodiment, the imaging sensor ~~can~~ may be configured~~, in particular,~~ in depth-imaging fashion, ~~i.e.~~ e.g., two image sensors~~, for example, are~~ may be used in order to obtain depth resolution of an object. A matrix or an array of image sensors ~~can~~ may also be used for this. ~~Also conceivable is a~~ A depth-imaging sensor that operates according to different physical principles, for example the time-of-flight principle or the principle of structured illumination, may also be used.

~~For self monitoring but also for other purposes, it may be advantageous to have~~ In an example embodiment, an illumination apparatus that is associated with the imaging sensor may be provided, e.g., for self-monitoring or other purposes.

~~Drawing~~ BRIEF DESCRIPTION OF THE DRAWINGS

~~Exemplified embodiments of the invention are depicted in the drawings and are explained in more detail in the description below.~~

~~In the drawings:~~

Figure 1 is a first block diagram of the imaging sensor according to an example embodiment of the present invention~~;~~.

Figure 2 is a second block diagram of the imaging sensor according to an example embodiment of the present invention~~;~~.

Figure 3 is a third block diagram of the imaging sensor according to an example embodiment of the present invention~~;~~.

Figure 4 is a fourth block diagram~~; and~~ of the imaging sensor according to an example embodiment of the present invention.

Figure 5 is a fifth block diagram of the imaging sensor according to an example embodiment of the present invention.

~~Description~~ DETAILED DESCRIPTION

Highly developed high-resolution image-producing or depth-image-producing measurement systems are of increasing interest for applications in automotive engineering. ~~Video~~ For example, such systems may be applied to video-based assistance systems and safety systems ~~are envisioned here as particular applications~~. The more responsibility ~~that is to be~~ transferred from human beings, the more reliable such a

measurement system must be. ~~In that context, the~~ The ability of the system to detect a failure and initiate suitable actions ~~is also very~~ may therefore be important. ~~The~~ In an example embodiment of the present invention ~~proposes~~, an imaging sensor ~~of this kind that has this capability~~ may be provided that may be configured for self-monitoring~~, that~~. The imaging sensor ~~being~~ may be built into a motor vehicle. The ~~essence of the invention is the integration of this~~ self-monitoring ~~functionality~~ capability may be integrated into a high-resolution image-producing or depth-image-producing measurement system.

Since such measurement systems for measured value generation may have at least one high-performance evaluation unit, ~~a self-monitoring functionality is implemented by the fact that signal processing methods are used, by way of the evaluation unit,~~ self-monitoring may be implemented via the evaluation unit. The evaluation unit may use signal processing to ascertain, from the sensor signals themselves, variables that allow conclusions as to the ~~functional~~ operational capability of the sensor and the measurement system. Previous knowledge and empirical knowledge about signal profiles ~~is~~ may be evaluated in suitable fashion. In the ~~simplest case~~ one example embodiment, a parameter that has been derived from the image signal ~~is~~ may be compared with a limit value or a limit value set that ~~is~~ may be stored in a memory associated with the imaging sensor.

~~Another possibility is to perform~~ In another example embodiment, an evaluation of the system status may be performed on the basis of several different variables. If limit values are exceeded or if a limited ~~functionality~~ operability (up to and including sensor failure) is identified in another fashion, ~~a corresponding status report is then~~

~~transmitted via a suitable interface, but at least the~~ failure of the imaging sensor ~~is reported. Otherwise the functional~~ may be reported. For example, a corresponding status report may be transmitted via a suitable interface. Otherwise the operational capability of the imaging sensor ~~is~~ may be transmitted via ~~that~~ the interface. The self-monitoring ~~can~~ may be performed during the initialization phase of the imaging sensor, at certain points in time, or continuously. The self-monitoring ~~can~~ may also be activated externally, ~~i.e.~~ e.g., by way of a higher-order system such as a diagnostic unit, or manually. ~~It is conceivable, in the case of activation by way of a diagnostic system, also to perform an~~ An expanded test program~~, since it is~~ may also be performed in the event of an activation by the diagnostic unit, since it may be possible, for example, to transfer pattern files or also to perform long-term tests.

Figure 1 is a block diagram that shows ~~the~~ an imaging sensor according to an example embodiment of the present invention ~~in a first block diagram. Physical process 10 (the scene) is~~. Scene 10, e.g., physical surroundings, may be imaged by sensor 12 as an image signal. ~~Sensor 12, together with~~ A measurement system 11 may include a sensor 12 and a processing unit 13~~, constitutes a measurement system~~. The image signal generated by sensor 12 ~~is~~ may be prepared and processed by processing unit 13. The measurement signal, i.e., the image signal, ~~is~~ may be transferred via a first interface 14 to further systems, for example to a control unit for occupant detection.

The status of the imaging sensor ~~which is presented here, and which was also determined~~ may be determined by the measurement system 11 on the basis of the image signal~~, is~~. The determined status may be transferred via a further interface 15. ~~As stated above, the~~ The status of the imaging sensor,

i.e., its self-monitoring, ~~is~~ may be performed ~~either~~, e.g., by utilizing previous knowledge about its invariant patterns, ~~or~~ empirical knowledge about measurement signal profiles ~~or~~, the redundancy of a network of sensors, or ~~by utilizing~~ time-related redundancy. ~~Interfaces~~ In one example embodiment, interfaces 14 and 15 ~~can also~~ may be combined into one interface, and ~~are then~~ may be separated only logically. The interfaces ~~here can be~~ may be, e.g., two-wire interfaces or ~~also~~ interfaces to a bus system.

Figure 2 is a block diagram that shows an imaging sensor that has more than one sensor for image acquisition and is thus also configured for depth-image production. Three sensors 22 through 24 are depicted here by way of example, although ~~it is possible to use~~ only two sensors or also more sensors may be used. Measurement system 21 ~~is~~ may therefore ~~constituted by~~ include sensors 22 through 24 and processing unit 25. ~~Physical process 20 (the scene) is~~ Scene 20, e.g., physical surroundings, may be imaged by sensors 22-24. Processing unit 25 ~~receives~~ may receive the image signals of image sensors 22 through 24, ~~processes~~ process them, and then, ~~as a function of~~ based on the evaluation of those image signals, ~~conveys~~ convey signals to interfaces 26 and 27 in order to transfer on the one hand the status of the imaging sensor and on the other hand the measurement signal itself. Sensors 22 through 24 ~~can~~ may be connected to individual interface modules of processing unit 25, but they ~~can~~ may also be connected to processing unit 25 via a multiplexer or an internal bus. ~~The~~ In one example embodiment, the imaging sensor ~~can~~ may be embodied in one physical unit in which interfaces 26 and 27 ~~are also integrated. Another possibility, however, is that no~~ may also be integrated. In an alternative example embodiment, these components may be disposed in a distributed fashion, without a housing ~~exists~~ for the entirety of these components~~, and~~

~~instead they are disposed in distributed fashion~~. Processing unit 25 ~~then, as described above, performs~~ may then perform the analysis of the image signal in order to perform the self-monitoring of the imaging sensor.

Figure 3 is a block diagram that shows the imaging sensor according to an example embodiment of the present invention ~~in a third block diagram~~. Two sensors ~~are present here, as~~, video cameras 31 and 32 ~~that are~~, may be connected to a processing unit 33. The latter ~~has~~ may have a program 34 for sensor data processing and a program 35 for self-monitoring. Self-monitoring ~~35 is also~~, facilitated by program 35, may be performed on the image signals of video cameras 31 and 32. In addition, processing unit 33 ~~controls~~ may control an illumination unit or a signal generator 36, for example in order to perform the self-monitoring by comparing self-induced patterns with their internal representation. Processing unit 33 ~~is furthermore~~ may be connected to interfaces 37 and 38 that may serve to transfer respectively the measurement signal, ~~i.e.~~ e.g., the image or depth image, and the status or the result of the self-monitoring. Measurement system 30 ~~thus comprises~~ may thus include processing unit 33, illumination unit 36, and sensors, e.g., video cameras 31 and 32~~, processing unit 33, and illumination unit 36~~. The overall imaging sensor ~~is~~ may be supplemented with interfaces 37 and 38. ~~Sensors 31 and 32 are embodied here as video cameras.~~ The output signals ~~are~~ may be conveyed to ~~evaluation~~ processing unit 33, e.g., an evaluation unit, which ~~performs~~ may perform suitable ~~processing steps~~ procedures such as image processing, correlation ~~methods~~ procedures, or triangulation in order to generate the spatial data. ~~This~~ The processing unit 33 may also~~, however, performs~~ perform suitable ~~processes~~ procedures for self-monitoring of the measurement system. In ~~this exemplified~~ an example embodiment, the output signals of the

~~stereoscopic~~ video measurement system ~~are~~ may be the image, the depth image, and the status signal of measurement system 30.

The table below lists potential problems that can result in limited ~~functionality~~ operability of the embodied measurement system. Columns 2 and 3 contain the appropriate data and signal processing ~~methods~~ procedures for identifying the limited ~~functionality~~ operability.

Problem	Data analyzed	Selection of self-monitoring ~~methods~~ procedures
Sensor is (partly) obstructed	Grayscale image of sensor 1	Utilize previous knowledge about invariant patterns: • Naturally occurring invariant features of the surroundings. • Invariant features induced automatically (e.g. using an illumination module), by the system. Utilize time-related redundancy: • Time-related analysis of sensor signal. • Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize empirical knowledge about measurement signal profiles: • Analysis of statistical parameters Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
	Depth image	see Grayscale image of sensor 1
Decalibration detection	Grayscale image of sensor 1	Utilize previous knowledge about invariant patterns: • Naturally occurring

		invariant features of the surroundings. • Invariant features induced automatically (e.g. using an illumination module) by the system.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
Errors in brightness setting	Grayscale image of sensor 1	Utilize empirical knowledge about measurement signal profiles: • Simple comparison of adjacent regions of sensor • Comparison with limit values • Comparison with qualitative signal profiles • Analysis of trends • Analysis of statistical parameters • Analysis of further spectral properties Utilize time-related redundancy: • Time-related analysis of sensor signal. • Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network
Errors in image sharpness (defocusing)	Grayscale image of sensor 1	Utilize empirical knowledge about measurement signal profiles: • Analysis of statistical parameters • Analysis of contrast spectrum

		• Analysis of further spectral properties Utilize time-related redundancy: • Time-related analysis of sensor signal. • Analysis of recorded dynamic processes.
	Grayscale image of sensor 2	see Grayscale image of sensor 1
	Grayscale images of sensors 1 and 2	Utilize redundancy of a network of high-resolution sensors: compare various individual sensor signals of the sensor network

~~A stereoscopic~~ In an example embodiment of the present invention, the video ~~-based~~ measurement system may be ~~regarded as a typical example of~~ a high-resolution image-producing or depth-image-producing measurement system, e.g., a stereoscopic video-based measurement system, to which many of the aforementioned signal-processing or pattern-recognition ~~methods can~~ procedures may be applied for self-monitoring. ~~A~~ In an example embodiment, a largely independent generation of the individual sensor signals~~, in particular, should make possible a~~ may provide powerful self-monitoring ~~functionality~~.

Figure 4 is a ~~fourth~~ block diagram of the imaging sensor according to an example embodiment of the present invention. A video sensor system 40 ~~has~~ may include a camera system 42 that ~~is~~ may be connected on the one hand to an image preprocessor 43 and on the other hand to an output of the video sensor system. Image preprocessor 43 ~~is~~ may be connected to a comparison unit 44 that ~~is~~ may be connected via an output to an evaluation unit 45 and via an input to ~~a~~ device 41 for structured illumination. Evaluation unit 45 ~~supplies~~ may supply the sensor status via an output of video sensor system 40.

Device 41 for structured illumination ~~radiates~~ may radiate structured light, constituting a reference pattern, into the surroundings of video sensor system 40, ~~in particular~~ e.g., onto a surface 47 on which the reference pattern ~~is~~ may be imaged. ~~That~~ The surface ~~is then~~ may be referred to as reference surface 47. Reference surface 47 ~~is~~ may be rigid and stationary. ~~Conceivable~~ Example reference surfaces ~~are~~ may be object surfaces present in the sensing region of video sensor system 40, for example a roof liner when the sensor is used to monitor a motor vehicle interior. ~~Also possible, however, are~~ In one example embodiment, special calibration elements may be provided that, for example, ~~are~~ may be mounted in a defined location and orientation during the manufacturing process.

Camera system 42, which ~~can comprise~~ may include one or more cameras, ~~senses~~ may sense the reference pattern on reference surface 47. The two-dimensional camera images ~~are~~ may be compared in comparison unit 44 to the reference pattern; the two-dimensional camera images ~~can~~ may also be ones that were prepared in the optional image preprocessor 43. That preparation can be a filtration. Comparison unit 44 ~~can~~ may have a memory unit in which, for example, the reference patterns ~~are~~ may be stored, if they are not conveyed from the unit for structured illumination in the form of a signal. The sensor status ~~is~~ may then be ascertained in evaluation unit 45 on the basis of the results of comparison unit 44. ~~The fact that~~ Whether the sensor is obstructed or unobstructed and/or the sensor optics are focused or unfocused and/or the optical image is distorted or undistorted ~~can~~ may be regarded, for example, as the sensor status. Evaluation unit 45 ~~can~~ may also contain a memory in which, for example, specific patterns ~~can~~ may be stored that ~~are~~ may be created upon comparison of the

reference pattern with the camera images of a faulty video sensor system.

With the device described above it ~~is~~ may be possible, for example, to identify a defocusing of the sensor by analyzing whether a sharp image of the reference pattern is present in the camera image. Complete or partial obstruction of the sensor ~~can furthermore~~ may be detected by checking whether the reference pattern is imaged in complete and undistorted fashion in the camera image. Distortions of the optical image may result in distorted imaging of the reference pattern in the camera image, and ~~can~~ may thus be identified using comparison unit 44 and evaluation unit 45. Further errors that ~~can~~ may be detected with this system ~~are~~ may be soiling of the optics, and misalignment of the absolute calibration. Here the resulting shift and distortion of the reference pattern ~~is~~ may be detected. An initial calibration or post-calibration ~~can in fact~~ may be performed on these data.

~~Device~~ In one example embodiment, device 41 for structured illumination ~~can~~ may be integrated into the video sensor. ~~A~~ In an alternative example embodiment, a device for structured illumination may be provided separate from the video sensor ~~is also possible, however, especially~~, e.g., in the manufacturing process ~~and~~ and/or for checking the video sensor at a repair shop. ~~In this case~~ According to the latter embodiment, a defined orientation of the device for structured illumination with respect to the video sensor ~~is necessary. With this procedure, therefore, in the simplest case~~ may be necessary. In an example embodiment, the video image of the structured illumination ~~is~~ may be interpreted directly. ~~An~~ In an example embodiment, an evaluation of a three-dimensional image ~~is~~ may also be possible.

Figure 5 is a ~~further block diagram~~ block diagram according to an example embodiment of the present invention. A video sensor system 50 ~~has~~ may have two cameras 52 and 53 that may supply their respective camera images to a unit 54 for determining three-dimensional measured values. A three-dimensional point cloud may then ~~results~~ result therefrom and ~~is~~ may be conveyed on the one hand to a signal preprocessor 55 and on the other hand to an output of video sensor system 50. Signal preprocessor 55 ~~is~~ may be connected to a comparison unit 56 to which a device 51 for structured illumination ~~is also~~ may be connected. Comparison unit 56 ~~is~~ may be connected via a data output to an evaluation unit 57 that in turn ~~outputs~~ may output the sensor status.

Device 51 for structured illumination ~~illuminates~~ may illuminate a reference surface in surroundings 58 of the video sensor. The reflected pattern ~~is~~ may be acquired by cameras 52 and 53. Unit 54 ~~determines~~ may determine the three-dimensional point cloud from the camera images based on the stereo measurement principle. In addition to determination of the three-dimensional point cloud, the two-dimensional camera images ~~can~~ may also be evaluated directly. ~~A further possibility lies in evaluating~~ In an example embodiment, the three-dimensional measured values may be evaluated using a range sensor that operates on the time-of-flight principle.

~~Abstract~~ ABSTRACT

An imaging sensor ~~that is~~ disposed in a vehicle ~~is proposed, that sensor being configured in such a way that it performs a self-monitoring. This can be accomplished on the basis of the~~ includes an evaluation unit for monitoring the imaging sensor's operability based on an image signal, for example, by an evaluation of invariant patterns ~~or~~, empirical knowledge about measurement signal profiles, ~~by~~ utilizing the redundancy of a network of sensors, or ~~by~~ utilizing time-related redundancy.

~~(Figure 3)~~